

# Scaling your Supply Chain

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# Introductions

- Chris Binz
- Paul Czerniewski
- Frank Scopacasa

# Agenda

1. Product readiness

2. Product costs

3. International vs domestic sourcing

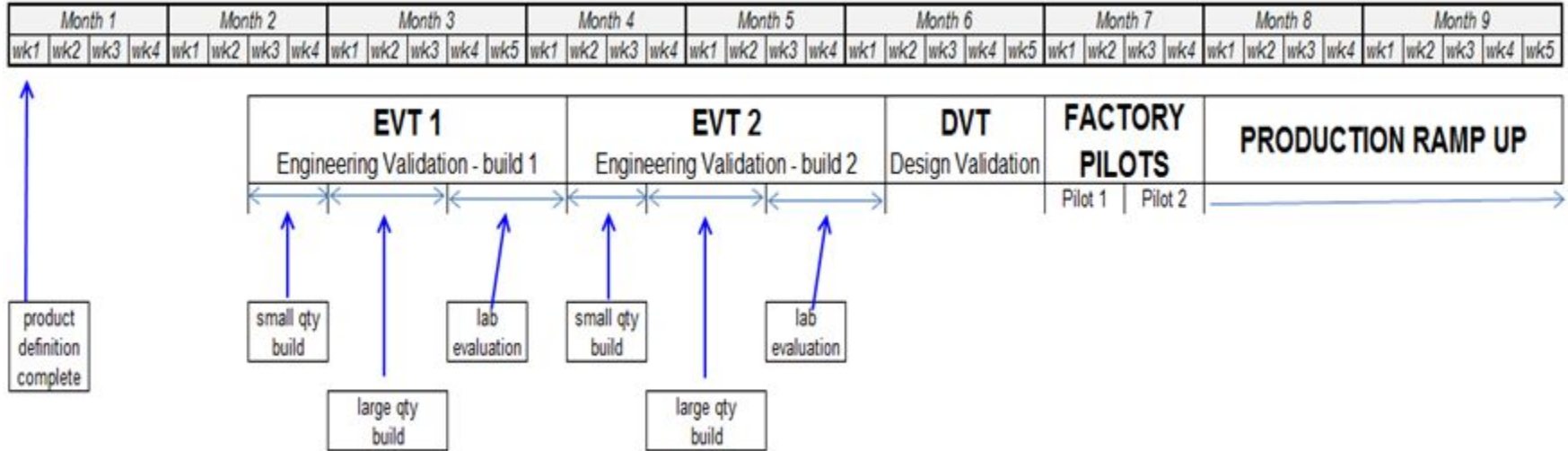
4. Finding and manufacturers and suppliers

5. Negotiating contracts and Quality agreements

6. Product Manufacturing test strategy

# Wireless Device Segment - Product Development Cycle

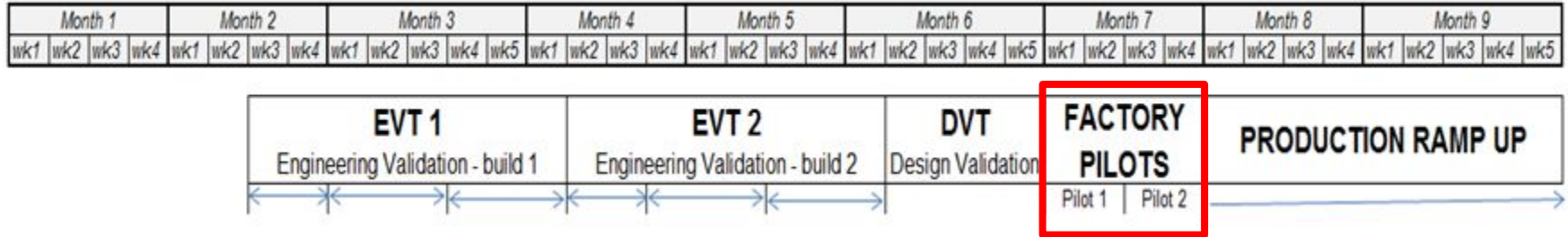
Industry norm = 6-9 month development cycle



- Rapid introduction of new technology
- High volumes at initial ramp
- Test Solutions and yields optimized in EVT phase
- Global coordination between Design & Manufacturing

# Ready to Ramp

**Factory Pilot is a critical checkpoint before moving to mass production phase**



- Quantity of units built during pilot will depend on product cost & typical rate
- Example: product costing hundreds of dollars per unit with typical production volumes of thousands per shift will execute pilots of 200-400 units
- Multiple Factory Pilot builds may be required to achieve ready to ramp goals

# Ready to Ramp - Typical Criteria and Checklist

**Factory Pilot is a critical checkpoint before moving to mass production phase**

Product Quality		Product Readiness		Supply Chain Readiness	
Incoming Material	R	Bill of Material / Component Specs	G	Material	R
Factory Yields	Y	Factory Work Instructions	G	Factory Capacity	G
Quality Audits / Out of Box	Y	Packaging / Labels	Y	Distribution	G
Tear Down / Accelerated Life Test	G	Software Readiness	R	Post Sales Support	Y
		Safety & Compliance	G		

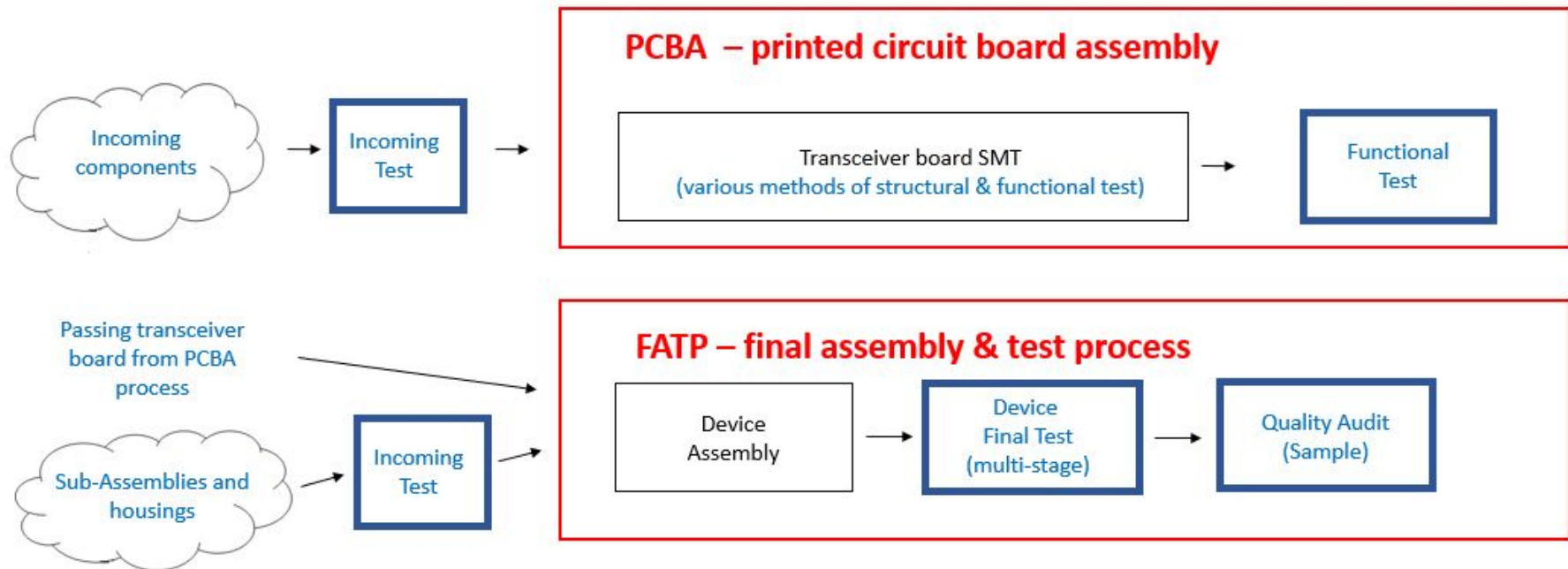
R	Issue blocks Ramp	Y	Issues exist but they are not Ramp blockers	G	No Issues
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- Quantity of units built during pilot will depend on product cost & typical rate
- Example: product costing hundreds of dollars per unit with typical production volumes of thousands per shift will execute pilots of 200-400 units
- Multiple Factory Pilot builds may be required to achieve ready to ramp goals

# Ready to Ramp - Product Quality

## Factory Process & Test Flow

Product Quality	
Incoming Material	R
Factory Yields	Y
Quality Audits / Out of Box	Y
Tear Down / Accelerated Life Test	G



# Ready to Ramp - Product Readiness

## Factory Process & Test Flow

Product Readiness	
Bill of Material / Component Specs	G
Factory Work Instructions	G
Packaging / Labels	Y
Software Readiness	R
Safety & Compliance	G

- Bill of Material / Component specs officially released and under formal version control
- Factory Work Instructions for PCBA and FATP (Final Assembly and Test)
- Software: Internal Regression test, Customer test
- Safety and Compliance: will vary depending on product and industry



# Ready to Ramp - Supply Chain Readiness

## Factory Process & Test Flow

- Material
  - PO release date
  - Payment terms
  - Factory request date (2 weeks before manufacturing)
- Factory Capacity
  - Agreed to Yields
  - 5 days/week, 1 shift/day, 11 hour shift
  - What is burst capacity?
  - What assembly or test stations are limiting capacity?
    - What is the cost to increase capacity by 10%, 25%, 50%
- Distribution
  - Identify a Logistics company
    - What is the minimum shipment size/weight where a 3PL becomes cost advantageous over FedEx or DHL
  - Identify a warehouse that can store, ship and possibly do minor customization
    - Receiving costs, pick costs, shipping costs
  - Trial run of X units to verify process
- Post Sales Support
  - Identify support tools required to answer customer inquiries
  - Identify support hours and clearly post to website

Supply Chain Readiness	
Material	R
Factory Capacity	G
Distribution	G
Post Sales Support	Y

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# Product Cost

## Economics of Mobile Phone Business

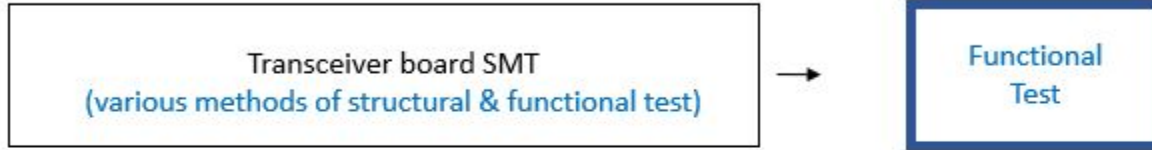
Item	Definition	Low tier Smartphone	High tier Smartphone
Direct Material (DM)	<i>cost of all parts that make up the phone</i>	\$130	\$250
Full Conversion Cost	<i>-cost to build the phone (includes DL, IDL, scrap, plant, &amp; equipment) -cost for shipping &amp; freight -cost of Warranty -cost of SG&amp;A</i>	\$20	\$30
Total Cost	<i>Material + Conversion cost</i>	\$145	\$280
Selling Price (ASP)	<i>Price to consumer at launch ASP=Average Selling Price</i>	\$199	\$600
Gross Margin	<i>Margin at launch</i>	27%	53%

- **Selling Price (ASP) to consumer erodes as competitors launch new devices making time to market critical**

# Product Cost - Factory Conversion / VA Cost

## Factory Process & Test Flow

### PCBA – printed circuit board assembly



### FATP – final assembly & test process



# Product Cost - Factory Conversion / VA Cost

## Factory Process & Test Flow

<u>VA Cost Quote - China</u>	<u>PCBA</u>	<u>FATP</u>	<u>TOTAL</u>
Direct Labor	\$ 0.75	\$ 1.95	\$ 2.70
Indirect Labor	\$ 1.40	\$ 0.55	\$ 1.95
Scrap	\$ 0.35	\$ 0.30	\$ 0.65
Plant	\$ 0.12	\$ 0.25	\$ 0.37
Equipment	\$ 1.10	\$ 0.35	\$ 1.45
SG&A (Selling, General, & Administrative)	\$ 2.15	\$ 1.80	\$ 3.95
Working Capital Financing cost	\$ 0.65	\$ 0.60	\$ 1.25
Manufacturing Margin	\$ 2.35	\$ 1.95	\$ 4.30
Warranty, RMA, Freight, Other	\$ 1.55	\$ 1.50	\$ 3.05
<b>Total Transceiver cost</b>	<b>\$ 10.42</b>	<b>\$ 9.25</b>	<b>\$ 19.67</b>

<u>VA Cost Quote - North America</u>	<u>PCBA</u>	<u>FATP</u>
Direct Labor		\$ 5.20
Indirect Labor		\$ 1.38
Scrap		\$ 0.62
Plant		\$ -
Equipment		\$ 0.40
SG&A (Selling, General, & Administrative)		\$ 3.05
Working Capital Financing cost		\$ 0.70
Manufacturing Margin		\$ 3.50
Warranty, RMA, Freight, Other		\$ 1.15
<b>Total Transceiver cost</b>		<b>\$ 16.00</b>

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# International vs Domestic sourcing considerations

Considerations	Domestic	International (Asia)
Intellectual Property Protection	✓	
Piece Part Cost		✓
Lead Time		✓
Ability to Quickly Scale		✓
Transportation Logistics	✓	
Follow-up Travel & Time Cost	✓	
Ease of Communications	✓	
Import/Export logistics & Duty	✓	
Legal Fall Back	✓	

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# Type of Manufacturers and Suppliers

## - Contract Manufacturers (CM)

Vertically integrated, one stop shop based on product specification. Handles everything from purchasing raw material through final product shipping. Generally capable of manufacturing most custom components internally along with final product assembly, testing and shipping.

Few Examples: Foxconn, Flextronics, Jabil, BYD

## - Final Assembly Test and Pack (FATP)

Similar to CM without the vertically integrated capability. Generally components are received from specialty suppliers used in final assembly, test and shipping. Component supplier may be selected by the FATP supplier or specified by the customer.

Few Examples: Ensky, Goldtek, compal,

## - Specialty Suppliers

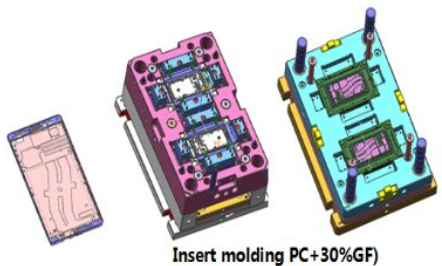
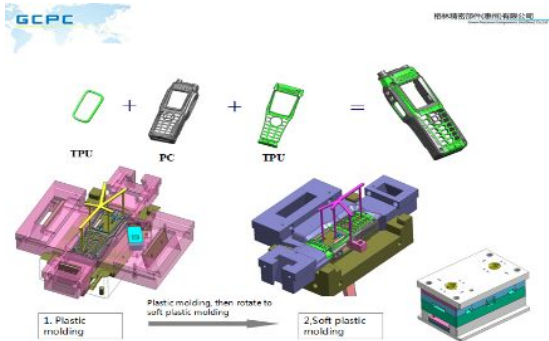
Custom mechanical and electrical components manufacturer, PC Boards, Displays, Plastic and Metal parts. Manufacture individual components to the customers specification. Components are shipped to the CM or FATP

Few Example: GCPC, Hi-P, KHVtec

# Vetting & Selecting CMs and Suppliers

- Find suppliers and CMs through your network
  - Avoid LinkedIn cold calls (unless you have time to vet the supplier)
- Identify any unique or specialty manufacturing processes
- Simplify your supply chain
  - Avoid shipping costs all over Asia where possible
- If you are manufacturing and purchasing in Asia, a supplier that has US headquarters or a presence in the US can be beneficial.
- Test your CM on any critical requirements
  - Protection of proprietary information - Continuously ask to see other products they are manufacturing
- Find a CM that has a process for vetting your start up
  - Immediately begin credit reviews to understand their expectations of you

# Custom Mechanical Components Processing



# Custom Mechanical Components Manufacturing

Plastic/ Polymers	Metal	Decorations	Secondary Operations
Injection Molding	Die Casting	Painting	Ultrasonic Welding
Compression Molding	Stamping	Anodizing	Heat Staking
Rotary Molding	Forging	NCVM/VM	Laser Welding
Blow Molding	CNC	Sand Blasting	Polishing
CNC	Extrusion	Brushed	Gluing
Die Cutting		Multi Color Printing	

# Tooling Life Expectancy

Type	Plastic	Metal Stamping	Die Castings
Prototype	< 2000	< 250,000	< 25,000
Soft Tools	< 250,000	< 250,000	< 25,000
Hard Tools	< 1,000,000	> 1,000,000	< 25,000

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# Manufacturing & Supply Agreements

## Manufacturing Service Agreement (MSA)

- Agreement between company and Contract Manufacturer
- Includes
  - Statement of Work defining services to be provided by CM
  - Defines rules of engagement for prototype and production scheduling
  - Defines payment terms
  - Expected yield tied to production quote
- These documents can be massive. Identify 5 to 7 key points and focus on them during negotiations. Have a “must have”, “preferred”, and “nice to have” target for each of the key points.

## Supply Agreement (SA)

- Agreement between company and custom component supplier. Might not have for all suppliers but are recommended for unique, high risk components
- Includes
  - Supplier commitment to meet the following
    - Order quantity (Within X% of PO total)
    - Order Price (No change from quotes)
    - Order Date (Up to X-days variation)
    - Quality (meeting your signed limit boards, providing FAI data)

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# Product Manufacturing Test Strategy

## 1. Design for Test for mindset

- Has largest impact mfg test cost, production quality, time to market and ability to ramp
- Provide inputs/guidelines/checklist to Software, Mechanical, & Electrical dev teams

## 2. Early involvement is critical -- get involved in concept stage

- Define test specification and drive for early test coverage

## 3. Define a test process flow and develop test systems for each step to be used in early prototype builds

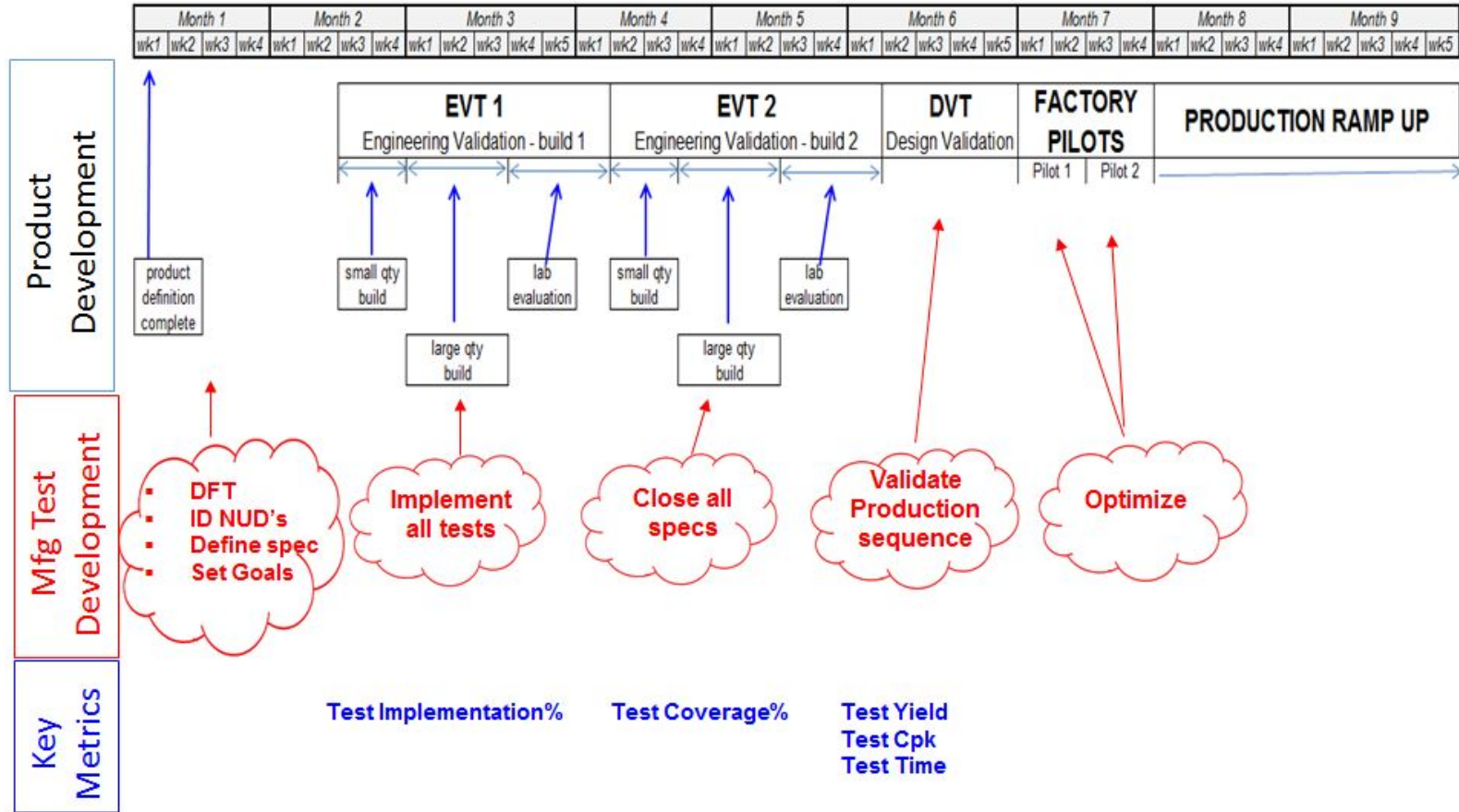
## 4. Optimize test process, specifications, and product design ahead of Manufacturing pilot

## 5. Data collection is critical. Use test data analysis tools and insure unit tracking & flow control are in place

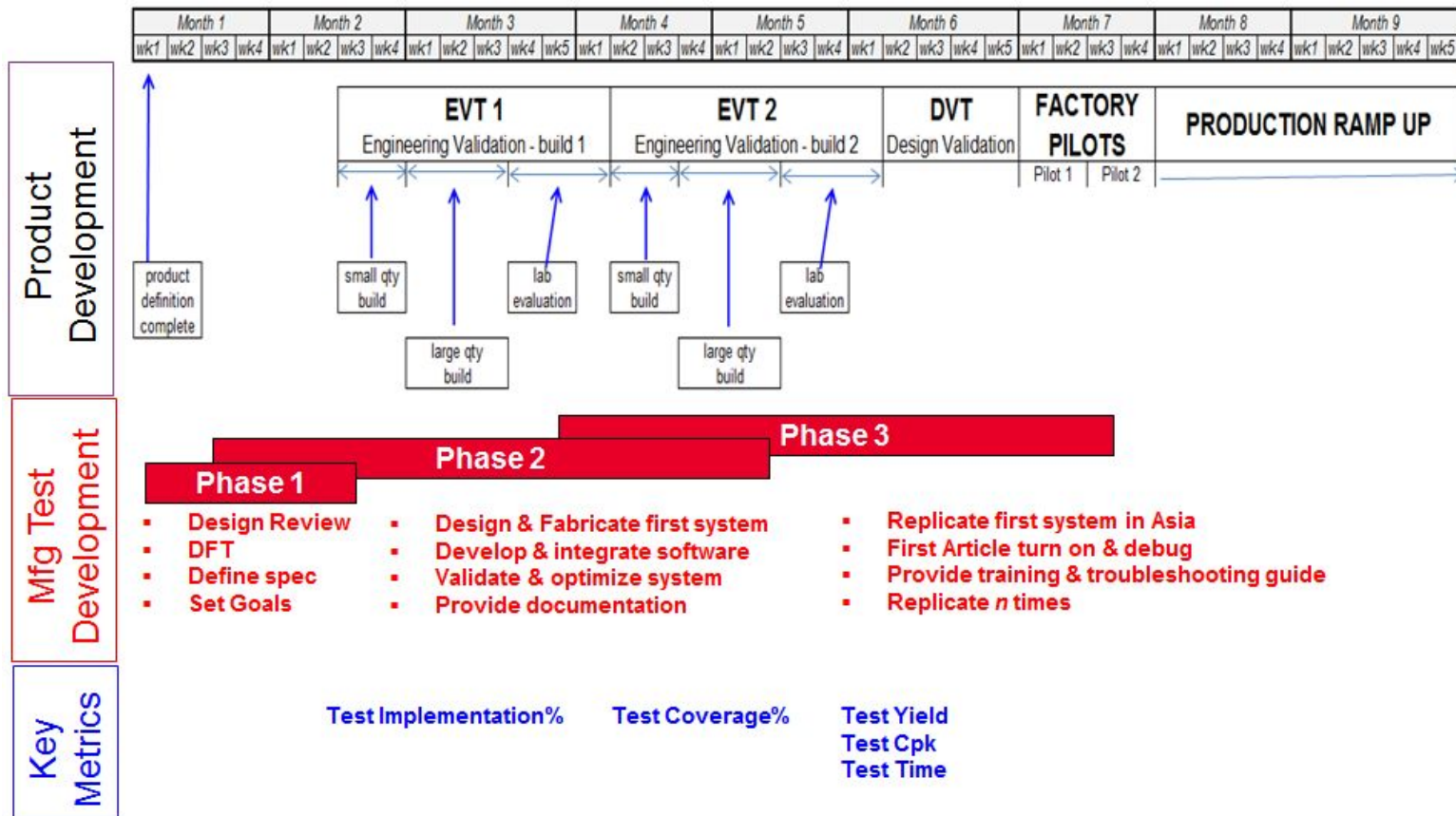
## 6. Engage with key upstream suppliers of critical components, modules, subassemblies

- Insure test specs and methodologies for key components align with end product specs

# Manufacturing Test Development - Key NPI Milestones



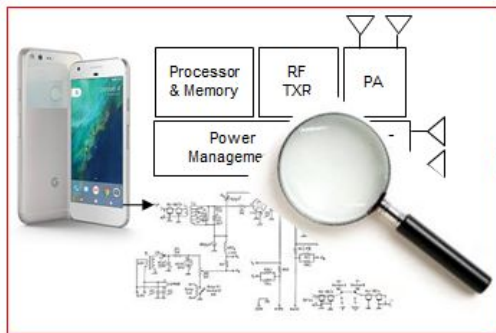
# Manufacturing Test Development Phases



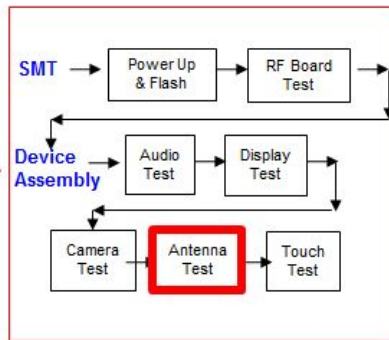
# Manufacturing Test Solution Development Process

- 3 phase approach
  1. Development of the Test Specification
  2. Design, Implementation, and Validation of the first system
  3. Scaling for volume production in Asia

# Development of the Test Specification



**Schematic & Block Diagram Analysis**



**Test Flow Definition**

A screenshot of a table defining test coverage. The table has two columns: 'Name' and 'Gr'. It lists various test cases and their corresponding grades.

Name	Gr
TAP Integration	1
TAP Test Plan	1
TX Cases	1
Transmit Mask	1
Center Freq Tolerance	1
Symbol Clock Tolerance	1
Transmit center frequency leakage	1
Transmit ramp-up and ramp-down	1
Transmit EVM (Control PHY)	1
TX Flatness	1
Transmit EVM (SC PHY)	1
RX Test Cases	1
Max input requirement	1
Receive sensitivity	1
PER	1
Angle of Arrival/Beam Steering	1
DUT Control Libraries	1

**Test Coverage Definition**



**Detailed Test Specification**

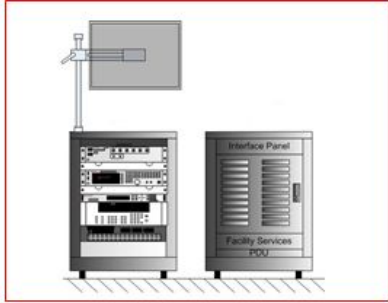
## Key Deliverables

- Test Project kickoff meeting
  - Identify team members + roles & responsibilities
  - Review schematic, block diagram, ME design, SW DUT control
  - Define test cases & procedures
- DFT assessment
- Schematic Test Coverage analysis
- Test Specification (test cases, procedures, spec limits)
- Establish test time and test yield goals

## Key Resources

- Device Expert
- DFT Expert

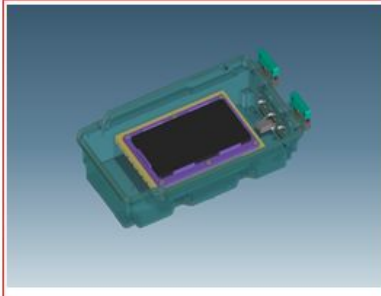
# Design, Implementation, and Validation of First System



## Test System Design

### Key Deliverables

- Test System design (NRE)
- Test Rack
- Test Controller
- Test Equipment
- RF Switching



## Test Fixture & Enclosure

### Key Deliverables

- Test Fixture design (NRE)
- Test Fixture (base & nest)
- RF couplers
- RF shield box



## Test Software

### Key Deliverables

- System Software
- Test Cases
- Data collection
- CIM system
- System Calibration



## Documentation

### Key Deliverables

- User Manual
- PM plan
- Troubleshooting guide
- Parts list
- Training plan
- Cost of Test analysis



## Verification

### Key Deliverables

- Repeatability study
- Gage R&R
  - Achieve P/T ratio <30%
- FMEA & Failure verification



# Scaling for Mass Production



## Production System Replication

### Key Deliverables

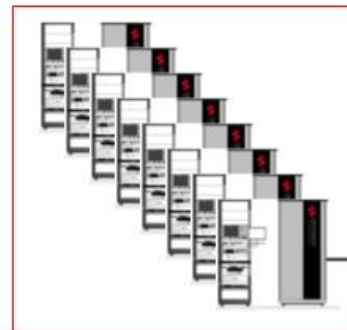
- Integrate rack & equipment
- Build and test rack in development lab
- Pack & ship to contract manufacturer



## First Article Turn on

### First Article Turn-On

- Site Prep
- Unpack & System Placement
- Connection to utilities
- Full bring up of first system
- Install test software
- HW and SW debug
- System Training



## Recurring System Orders

### Key Deliverables

- On site engineering support
- Check out of systems
- Initial Turn on
- System Diagnostics

# End to End Test

## IoT device

## Wireless Standard

## Wireless Access Point

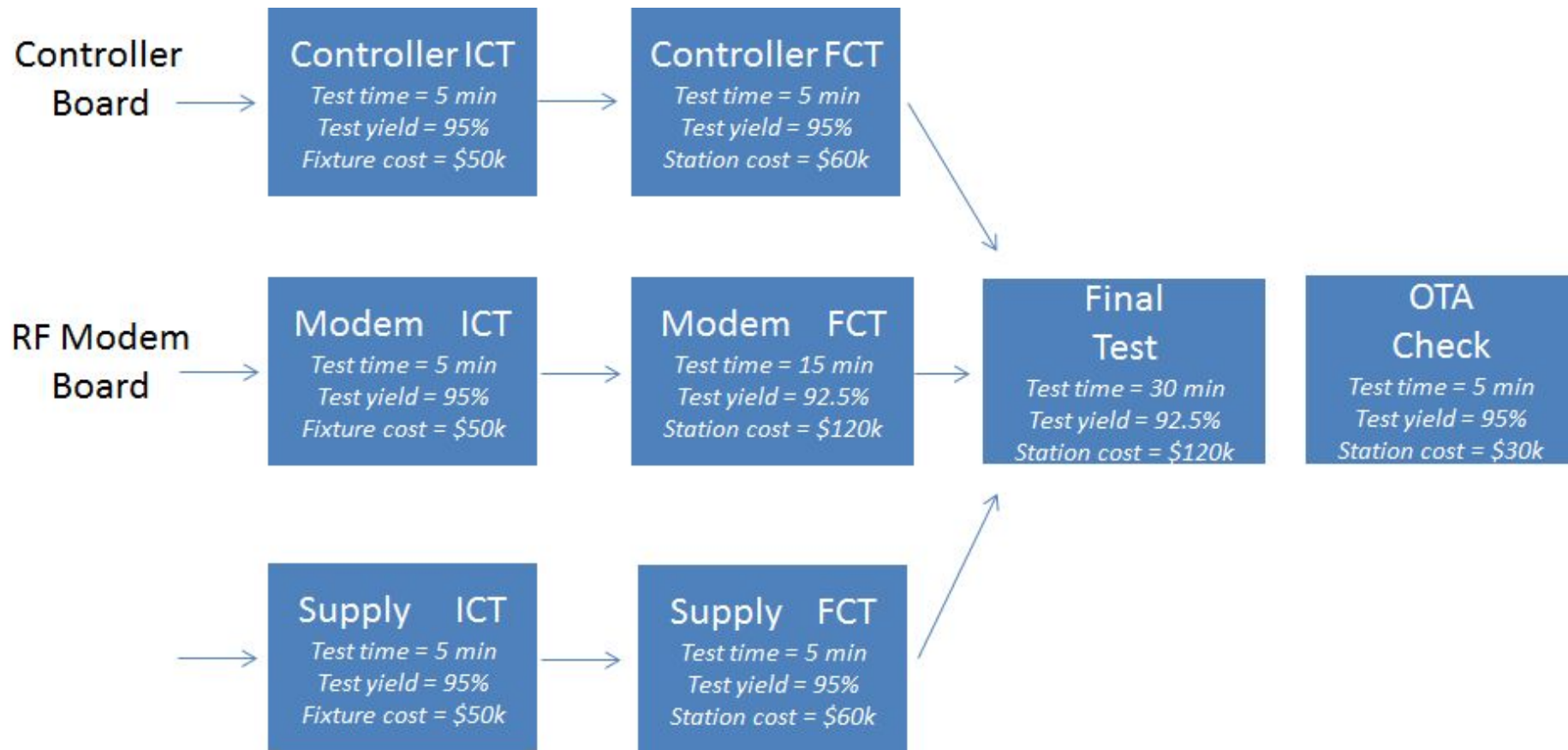
## Internet Service Provider

## Cloud & Application





# Factory Test Flow - 4G Base Station Test

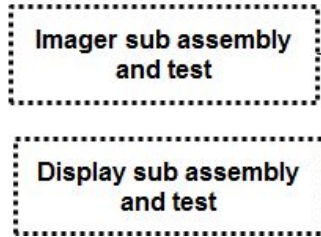


# Factory Test Flow - AR/VR Headset

## Main Board

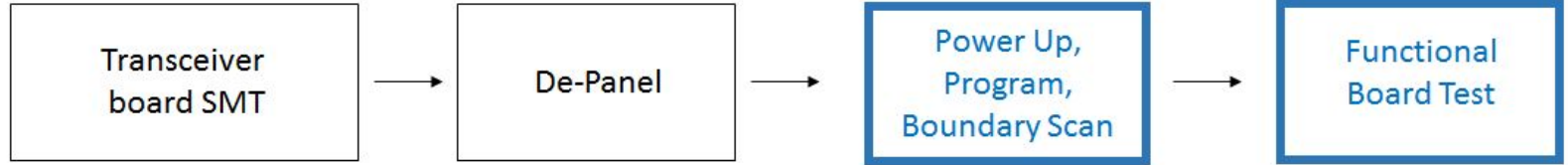


## Sub Assembly's

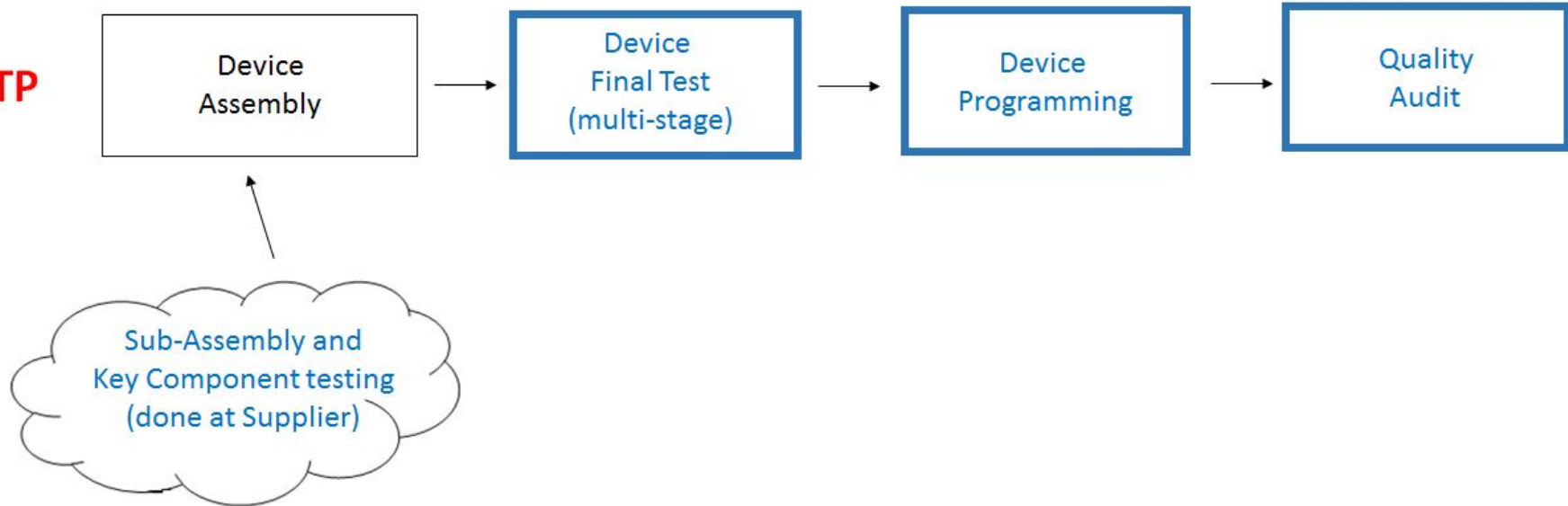


# Factory Test Flow - Mobile Device

**SMT**



**FATP**



# Operations Test Organization

## Test Software Development

- Software Platform (Windows, Linux, GIT, CC)
- Test Executive (TAP, Gondor)
- Test Architecture (application/drivers/DUT interface)
- Source Control & Process
- Source code development

## Test HW & System Development

- Systems & Racks
- RF switching & DUT/fixture interface
- Test Equipment selection & qualification
- Instrument optimization & utilization
- Test support documentation
- Test Equipment calibration
  - System cal cart
  - Track production test equipment
  - Ensure it remains in calibration
- Measurement uncertainty calculations and Gage R&R process
- Test methodology selection

## Factory Automation and Fixturing

- DUT fixtures
- Enclosures
- Automation handlers / robotics
- Interfacing to the product
- Manufacturing Execution System software
- Drive DFT requirements for fixturing & automation

## Test Data Collection / Analytics

- Results database
- Production failure database
- Reports
- Utilization / Downtime metrics
- Flow Control
- IT infrastructure for monitoring remote manufacturing

## Product Support

- Interface to R&D
- DFT services (chip, board, phone)
- Definition of production test spec
- Determine test flow & test plan for specific products
- Test time & measurement optimization
- Statistical analysis of prototype and pilot data
- Temperature/Environmental variation testing
- Launch test process to Contract Manufacturer
- EMS management

## Domain Experts >> *specific to products being supported*

- RF test & chipsets
- Digital buses and standards
- Imager Test
- Audio test
- OTA/Antenna test
- Display test
- ICT/Boundary Scan
- Flashing

# World Class Manufacturing Test

- **Organizational Charter**

- Clarity of mission (Cost, Quality, Delivery)
- Linkage/alignment across Global sites
- Understanding of core vs context
- Optimized manufacturing strategy (internal factories vs contract manufacturing vs ODM)

- **Data Driven**

- Global data repository
- Dashboards
- Global Reports
- SPC with Alarms & Triggers

- **People and Process**

- Best in class talent and leadership
- Team development & training plans
- Succession plans
- Constantly strives for continuous improvement

- **New Product Introduction**

- Engages design team during product concept stage
- Drives Design for Test into product development (PD)
- Co-develops production test requirements with PD
- Understands key test metrics (yield, test time, Cpk, NTF)
- Implements all production tests on early proto type builds
- Optimizes of production test solution ahead of ramp start

- **Global Test Platform Strategy**

- Leverages common test hardware, test software, and data collection systems across product portfolio
- Drives a standardized test flow across common products enabling efficient product changeover and factory flexibility

- **Manufacturing Optimization**

- Optimizes equipment utilization through implementation of parallel test techniques
- Understands & optimizes critical test metrics (DFT, GR&R, Cpk, Yield, Testtime, Utilization, cost of test)
- Able to measure and improve delivered quality to end customer
- Proactive Maintenance procedures